# The Impact of Rapid Snowmelt on Soil Erosion: Analysis of NPK Concentration, pH level, and Organic Matter Content

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ABSTRACT

This study explores **soil health** in the area of Grand Forks, ND, a semi-arid region of low altitude in the Northern Midwest region of the U.S. which experiences high snowfall and low temperature. In recent years, there has been a decrease in snowfall and an increase in temperature. This temperature increase has resulted in rapid snowmelt. **Rapid snowmelt** results in excess water, leading to **surface runoff** that may cause **soil erosion**. Previous research has established a connection between rapid snowmelt and erosion. However, many of these studies have focused on the physical aspects of soil health (such as porosity, infiltrability), rather than chemical aspects of the erosion. This study seeks to (1) provide insight into recent **climate** alterations in the Northern Midwest, (2) establish a connection between climate altercations and **chemical changes** in soil health, and (3) establish connections between chemical variables (NPK, pH, organic matter) and the geologic functions of the soil environment. To test the hypothesis, data was gathered from the National Weather Service to summarize recent climate factors that would affect soil health, including precipitation in the form of snowfall and rain, as well as temperature averages. Fieldwork was conducted to collect soil samples in the area surrounding the Red River Valley, based on **proximity to a water source** and **elevation** for lab analysis. Climate data confirmed that the average temperature of Grand Forks during the winter months have been increasing, although not in a linear manner. Tests confirmed the pH levels of

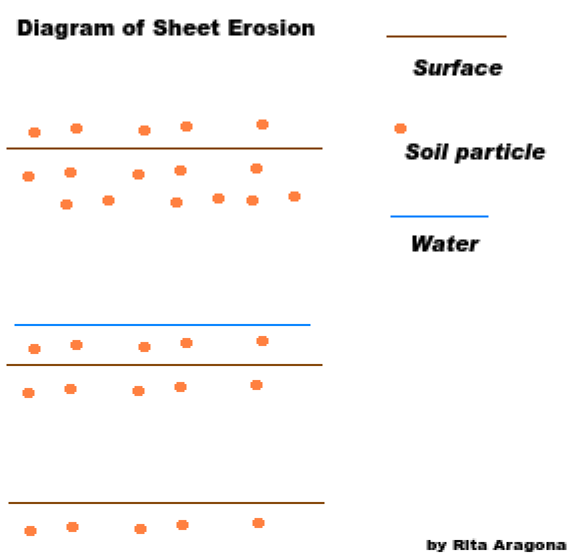
soil surrounding the Red River Valley is alkaline, and above the range that allows the most successful plant growth. However, proximity to a water source was not proven to be an impactful variable in the soil pH, and the Northern Plains don't display sufficient elevation levels to analyze how slope functions as a variable in the surface runoff of snowmelt. Organic matter tests yielded insufficient results, due to inaccuracies or errors in testing. If water proximity didn't play a role in the pH of soil, the Red River isn't causing elevated pH. This may support the hypothesis of rapid snowmelt elevating pH.

**Key Terms**

*Soil health, precipitation, rapid snowmelt, surface runoff, soil erosion, NPK concentration, pH level, organic matter, climate, temperature variability, sunlight exposure, elevation, water proximity*

## 1. Introduction

### WHAT IS EROSION? ITS CAUSES AND EFFECTS




Surface runoff is a process where water moves across the surface of an area, removing soil particles. When surface runoff is severe enough, this process may be referred to as water erosion, where soil stability and nutrition are negatively impacted. (A.A. Firoozi, 2024) Soil stability refers to the structural properties of soil, while nutrition refers to the chemical elements that support life. Rapid snowmelt may be a cause of surface runoff and water erosion, as it provides an area with an increase in available

water. The soil erosion explored in this paper is called sheet erosion, where the topmost layer of soil is slowly removed, eventually resulting in significant fertility loss.

The process of snowmelt in cold regions is primarily driven by precipitation in the form of rain. (Yang et al., 2022)(Z. Wu and H. Fang) Rainfall contributed to snowmelt through providing energy in the form of heat.

## ASPECTS OF SOIL HEALTH

Soil resides on Earth's surface, characterized by different horizontal layers and composed of solids, liquids, and gasses. These include minerals, organic material, water, and air. (USDA)

Factors that affect soil heath include structure, texture, chemistry, organic matter, infiltration, retention and movement of water. (UNACR)

| pH Levels | Minerals | Air | Water | Organic Material |
|---|---|---|---|---|
| 5.5 - 7.5 | 45% | 25% | 25% | 5% |

**The following chart demonstrates the healthy soil composition, with information provided by UCANR*

## pH LEVEL

At a macroscopic level, pH refers to how acidic or basic (alkaline) a substance is (EPA, 2024). At a microscopic level, it refers to the concentration of H+ ions relative to H- ions. H+ represents a positive ion, while H- represents a negative ion. If there are more H+ ions, the substance is acidic, and if there are more H- ions, the substance is alkaline. pH is important when studying soil because plants require a certain pH range to germinate and grow. The pH scale has a range of 0 to 14, with 7 being neutral, less than 7 is acidic, and greater than 7 is alkaline. The best pH value of soil ranges from 5.5 pH to 7.5 pH, although this can vary depending on the plant species.

Northern, cold regions generally possess acidic soils (Barrow, Hartemink, 2023), while arid and semi-arid regions generally possess alkaline soils (Batjes 1995; Simonson 1995)(Barrow, Hartemink, 2023). Because Grand Forks is a Northern, cold region, predicting its soil would be acidic might follow. However, because Grand Forks is also a semi-arid region, predicting its soil would be alkaline might also follow. The soil pH of Grand Forks is therefore not easy to predict based on its geographic information.

pH value may affect the solubility of soil and the ability of nutrients to be absorbed by plants (Barrow, Hartemink, 2023) The more basic or alkaline the solution of a soil is, the faster the organic matter within the soil decomposes. This decomposition of organic matter is where nitrogen in soil originates (see the nitrogen cycle). Conversely, the more acidic the solution of the soil, the slower the organic matter decomposes, leading to a lack of available nitrogen and an accumulation of organic matter.

**MINERALS**

Minerals are one of the inorganic elements of soil (USGS), and a key component of soil fertility. Minerals are characterized by their unique and organized internal structure, which provide efficient surfaces of nutrient storage for plants. Because these surfaces are unique, they provide different advantages and degrees of nutrient supply and retention. (University of Hawai'i)

Nitrogen (N), phosphorus (P), and potassium (K), collectively known as NPK in soil analysis, are vital mineral nutrients of soil for successful plant growth. (Khanlofah, et. al., 2022) Why are these minerals important? How do they function within the context of soil and contribute to plant growth? Nitrogen is important in the process of photosynthesis by assisting in the synthesis of chlorophyll pigments. (Khanlofah, et. al., 2022)

Phosphorus is partly responsible for the productivity of cell division, and also contributes to how energy is distributed and stored within plants. (Khanlofah, et. al., 2022) A plant lacking in P availability will therefore not reach maturity.

Potassium (K) plays a role in crucial steps of photosynthesis; it allows for water osmosis in plants, which contributes to the movement or distribution of carbohydrates (the byproduct of photosynthesis). It also serves as a catalyst for enzymes, triggering the production of ATP, an important component in the process of photosynthesis. (UMN)

**TEXTURE AND PARTICLE DISTRIBUTION**

*This chart has been adapted from the chart made available by the University of Hawai'i*

| | Sand | Silt | Clay |
|---|---|---|---|
| Size | 2.0 mm - 0.05 mm | 0.05 mm - 0.002 mm | < 0.002 mm |
| Texture | Gritty | Buttery | Sticky |
| Traits | Visible, low surface area, excessive drainage | Not visible, creases water holding capacity of soil | High surface area, high water holding capacity, very porous, charged surfaces that attract and hold nutrients |

Particle size is a property of soil that allows us to sort soil into different categories and describe their texture.

**ORGANIC MATTER CONTENT**

Organic matter refers to carbon-based, living or dead components of soil, and may include simple life or complex life forms that contribute to soil fertility. As they die and decompose, they provide minerals to the soil as a kind of natural fertilizer. Besides carbon, they may also include,

nitrogen (N), phosphorus (P), sulphur (S), potassium (K), magnesium (Mg), calcium (Ca) and a whole range of micronutrients (e.g. copper, (Cu) and zinc (Zn). (AHDB)

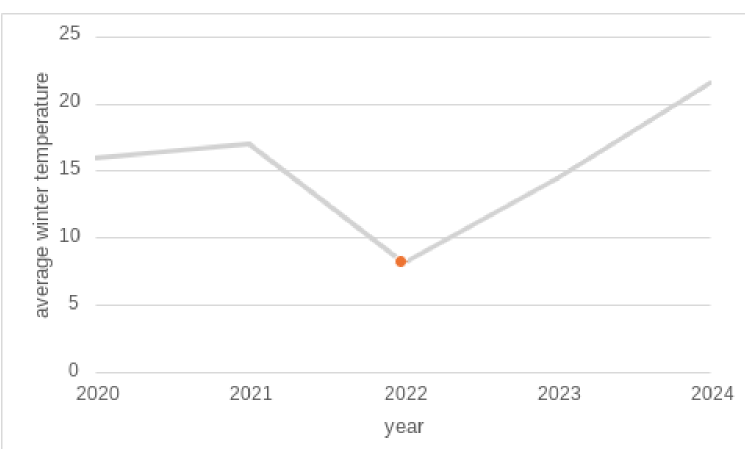
CLIMATE DATA: PRECIPITATION, EVIDENCE OF TEMPERATURE INCREASE

*In this section, I will discuss how climate, especially the threat of climate change, is involved in this area of research, drawing specific data from weather reports of the Grand Forks area. This project depends on short-term climate data (which I will define as being from November, 2024 to April of 2025 – roughly the period of time when snowfall occurred). rain*

Temperature Data

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 9.4 | 10.0 | 23.4 | 35.7 | 52.2 | 68.5 | 72.7 | 68.3 | 56.9 | 38.3 | 30.5 | 21.0 | 40.6 | 16.0 |
| 2021 | 17.5 | 5.3 | 34.3 | 40.9 | 53.2 | 69.3 | 73.0 | 69.7 | 63.0 | 49.4 | 30.3 | 10.7 | 43.1 | 17.0 |
| 2022 | 0.7 | 1.1 | 22.0 | 31.8 | 54.8 | 66.8 | 71.0 | 69.1 | 60.2 | 46.7 | 25.6 | 8.5 | 38.2 | 8.1 |
| 2023 | 9.3 | 9.5 | 12.6 | 33.2 | 62.4 | 71.6 | 67.4 | 68.3 | 63.7 | 45.4 | 30.9 | 26.4 | 41.7 | 14.5 |
| 2024 | 13.9 | 26.3 | 27.5 | 43.8 | 56.1 | 64.4 | 73.2 | 69.1 | 67 | 50.5 | 32.0 | 18.5 | 45.2 | 21.6 |
| 2025 | 9.4 | 10.1 | 30.3 | 42.7 | | | | | | | | | | 16.6 |

*This information has been provided by the National Weather Service. Temperatures are in degrees Fahrenheit.*




The highlighted data designates the winter months. Although there isn't a completely linear inclination of temperatures over the years

(2022 was lower than 2021 and 2020), you can see trends of temperature increase. The average temperature of each winter month (December - March) was averaged out to find discrepancies. The average winter temperature of 2022 was 6.4°F lower than the average winter temperature of 2023. The average winter of 2023 was 7.1°F lower than the winter of 2024.

Rainfall Data

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 0.78 | 0.12 | 0.26 | 0.94 | 1.05 | 5.90 | 6.70 | 2.41 | 0.30 | 0.37 | 0.12 | 0.40 | 19.4 | 0.39 |
| 2021 | 0.30 | 0.16 | 0.23 | 0.89 | 2.29 | 2.45 | 0.42 | 5.06 | 1.37 | 3.48 | 1.12 | 1.36 | 19.1 | 0.51 |
| 2022 | 0.62 | 0.88 | 0.30 | 5.47 | 6.09 | 2.16 | 4.59 | 1.42 | 0.53 | 0.17 | 0.52 | 1.57 | 23.3 | 0.84 |
| 2023 | 0.12 | 0.28 | 1.05 | 1.83 | 1.12 | 2.22 | 1.87 | 1.14 | 2.60 | 2.17 | 0.10 | 0.93 | 15.4 | 0.34 |
| 2024 | 0.26 | 0.23 | 0.17 | 2.02 | 4.21 | 5.32 | 3.18 | 4.83 | 0.43 | 0.61 | 1.55 | 0.77 | 23.6 | 0.36 |
| 2025 | 0.28 | 0.22 | 0.45 | 1.61 | | | | | | | | | | |

*This information has been provided by the National Weather Service.*

Snowfall Data

| | Jan | Feb | Mar | Apr | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|
| 2019-2020 | 20 | 16 | 11 | 5 | 6 | 2 | 13 |
| 2020-2021 | 3 | 2 | 1 | 2 | 1 | T | 3 |
| 2021-2022 | 9 | 11 | 8 | 9 | 0 | 4 | 8 |
| 2022-2023 | 12 | 13 | 19 | 16 | 0 | 5 | 15 |
| 2023-2024 | 5 | 3 | 1 | 0 | 4 | 3 | 3 |
| 2024-2025 | 6 | 3 | 3 | 1 | 0 | 3 | 4 |

*Monthly highest snow depth for Grand Forks Area, ND. Provided by the National Weather Service.*

You can see a clear decrease in the highest snow depth since 2019.

**EXPERIMENT**

My hypothesis for this experiment is as follows

In recent years, there has been an increase in temperature in North Dakota, resulting in the occurrence of rapid snowmelt. This rapid snowmelt leads to excess water and surface runoff, causing soil erosion. Specifically, I hypothesize rapid snowmelt is causing:

a. **Decreases in NPK**
b. **Increases in pH levels**
c. **Decreases in organic matter**

Decreases in NPK are caused by the ratio of NPK to water increasing. Soil (and its composite minerals, NPK) is the solute in this chemical relationship (let's designate it as y). Water from snowmelt is the solvent (designate it as x). The product they form after being physically combined is a solution (xy). The more solvent (water) there is, the more diluted the solution. If we view this as a ratio, where y:x becomes $y:x^2$. The total amount of water has increased, diluting the solution.

Increases in pH levels are also caused by the water increase. Water has a neutral pH of 7, meaning that it is neither alkaline or acidic. An acidic substance will have a pH less than 7 ($y < 7$). As water is added to an acidic solution, its pH continues to increase. If enough water is added, the pH eventually reaches 7 or higher. I assert this is what occurs during rapid snowmelt, as water levels increase, the soil is diluted until it reaches a neutral or above neutral pH.

Organic matter is any carbon-based substance (living or dead). It contributes to the soil as a fertilizer by releasing minerals as it decays. Due to excess water levels, the organic matter would decrease due to the impact of leaching, or the process of materials being removed by surface runoff. (Hou, et. al., 2020)

## FIELDWORK AND DATA COLLECTION

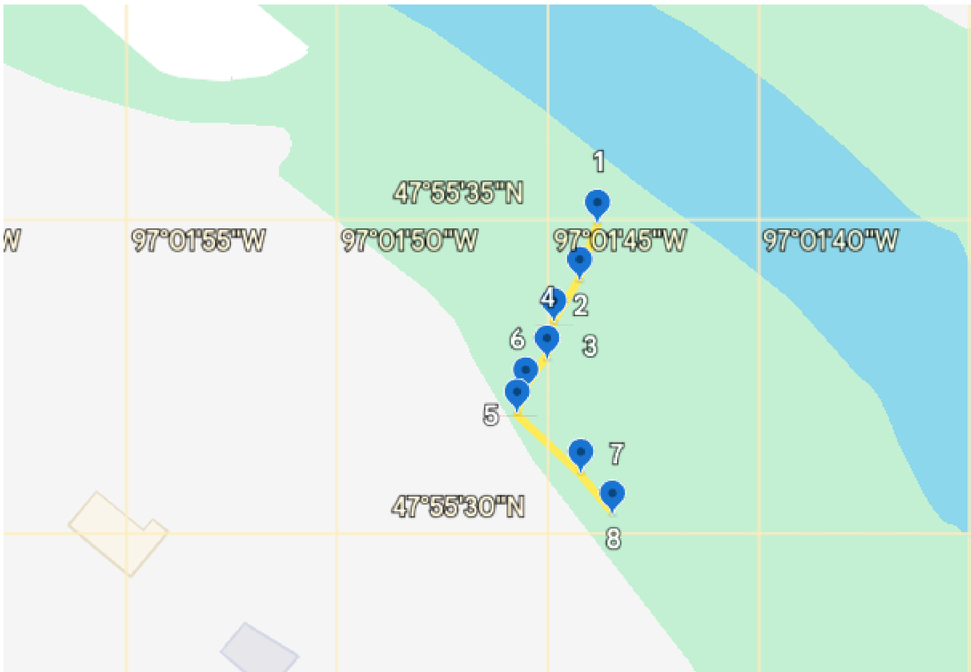
An integral part of this experiment was collecting soil samples. I made use of GIS software to do this, which displays images of the Earth. I used Google Earth, a kind of GIS software, to measure the distance of my location from water proximity, collect specific coordinate points, and measure elevation of each coordinate. 8 soil samples were collected around the Red River Valley, at a depth of 6 inches.

## PROCESS AND METHODS

1. I collected soil samples in the Grand Forks area based on slope and proximity to water.

| Sample # | Coordinates | Elevation | Water Proximity |
|---|---|---|---|
| 1 | 47°55'34"N 97°01'43"W | 255 m. | 30.84 m |
| 2 | 47°55'33"N 97°01'44"W | 252 m. | 58.89 m |
| 3 | 47°55'33"N 97°01'44"W | 261 m. | 82.35 m |
| 4 | 47°55'32"N 97°01'45"W | 252 m. | 99.38 m |
| 5 | 47°55'32"N 97°01'45"W | 252 m. | 118.4 m |
| 6 | 47°55'31"N 97°01'45"W | 252 m. | 129.77 m |
| 7 | 47°55'30"N 97°01'44"W | 253 m. | 133.43 m |
| 8 | 47°55'30"N 97°01'43"W | 253 m. | 138.35 m |

*Imagery of the Grand Forks Area where soil samples were collected. Each landmark point designates the specific coordinates where a sample was collected. The image includes the Red River, which the water source the above table refers to.*





Images of Red River Valley and the coordinates of sample origins. Google Earth ©

MEASURING pH LEVELS

*"pH is a property of liquids not of solids. We're measuring the pH of a solution in contact with a soil; the pH we determine depends on the solution we use and on the net charge carried by the soil." (Hartemink, A. E., & Barrow, N. J. 2023)*

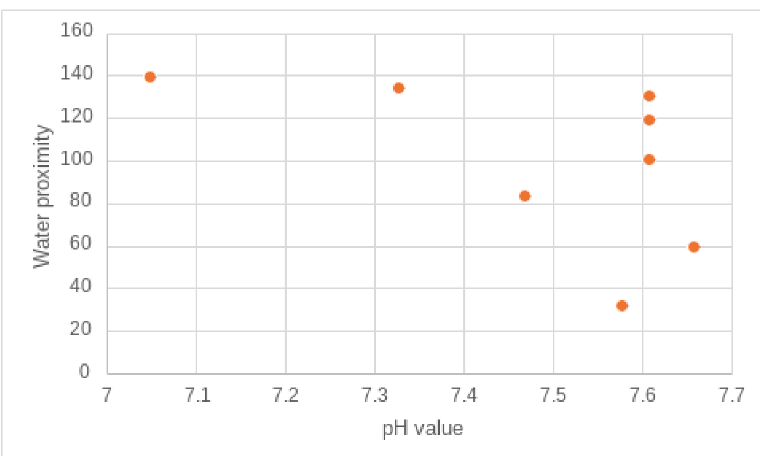
2. Divide samples for each procedure into different beakers (15 g in each beaker)
3. Add enough calcium chloride[1] solution to create a 1:2 solute to solvent ratio (30 mL of calcium chloride)
4. Measure the pH levels of each sample (using 0.01 M calcium chloride solution so that the pH is not increased)
5. Clean equipment after each measurement

The reaction rate of soil and calcium chloride was unknown. Therefore, a specific time to measure the pH wasn't determined. As a solution, two readings were conducted; one at approximately 5 minutes, and the second reading at approximately 30 minutes. Then, the average between the readings was calculated. There aren't clear patterns between the changes in pH between readings – 50% of the pH readings increase, and 50% of the pH readings decrease. However, all of the samples had a pH slightly above neutral. For the purposes of analyzing data, I will refer to the second reading, assuming that it more accurately shows pH thanks to an extended reaction period between the soil and calcium chloride.

*There were some errors in measuring the soil. I tried to get it as close to 15 g as possible but there were some inconsistencies (average inconsistency of 0.0147).

| | Reading #1 | Reading #2 | Average Reading | Water Proximity |
|---|---|---|---|---|
| Sample 1 | 7.12 pH | 7.58 pH | 7.35 pH | 30.84 m |
| Sample 2 | 7.82 pH | 7.66 pH | 7.74 pH | 58.89 m |
| Sample 3 | 7.42 pH | 7.47 pH | 7.30 pH | 82.35 m |
| Sample 4 | 7.60 pH | 7.61 pH | 7.61 pH | 99.38 m |
| Sample 5 | 7.33 pH | 7.61 pH | 7.47 pH | 118.4 m |
| Sample 6 | 7.71 pH | 7.61 pH | 7.66 pH | 129.77 m |
| Sample 7 | 7.44 pH | 7.33 pH | 7.39 pH | 133.43 m |
| Sample 8 | 7.41 pH | 7.05 pH | 7.23 pH | 138.35 m |

*Chart created by Aragona, Rita on MS Excel*




The sample (#8) furthest away from the major water source (at a distance of 138.35 m) displayed the lowest pH, closest to neutral (7.05 pH). Results confirmed the basic hypothesis; pH of collected samples would be alkaline due to the presence of excess water diluting the soil and any of its potentially acidic components. However, the details of my hypothesis weren't confirmed. I assumed that the pH would be affected by proximity to the Red River (the closest water source), but this proved to be wrong. Sample #1 was closest, but it didn't exhibit the highest pH (in the 1st, 2nd reading or the

averages). Although, the sample (#8) furthest away from the water source displayed the lowest pH on the second reading.

The highlighted samples have the same pH of 7.61, and the elevation of where they were collected was also 252 m. This could suggest a pattern or position correlation between elevation and pH, but it could also be a coincidence due to the limited sample size and the lack of diversity in samples' elevation. Especially because there was no correlation between elevation and pH found in the other samples.

The basic assumption that the pH value of soil in Grand Forks ranges from neutral to alkaline is true. However, due to lack of diversity in soil samples' elevation, it's difficult to determine if this is directly due to the impact of rapid snowmelt or from another variable. Water proximity doesn't seem to play a major role.

MEASURING ORGANIC MATTER CONTENT

We attempted utilizing the "loss on ignition method," where each soil sample is weighed, then heated to 400 degrees Celsius, and weighed again to burn away the organic matter. The sample is then weighed a second time, and both weights are subtracted. The difference is supposedly the amount of organic matter originally contained in the samples.

Formula: (original weight) - (weight after heat exposure) = organic matter content

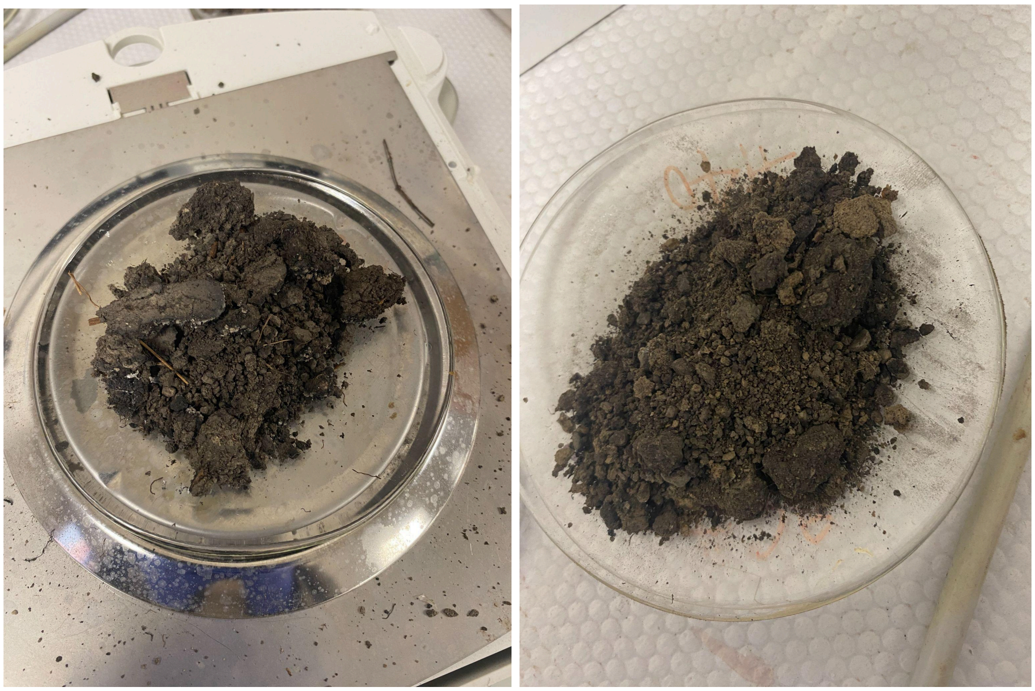
ADAPTING METHODS

The oven housed in the Abbot Hall lab didn't display a sufficient temperature setting of 400 degrees Celsius (it was 400 degrees Fahrenheit), so we weren't able to use it for the ignition method. We still used the oven to reduce or rid the samples of moisture content. Before, the samples were a darker, richer color displaying water content. We think that the oven reduced the water levels of each sample, making them dry.

We then used a torch, reaching 1982 Celsius. There were many challenges in completing this part of the experiment. The temperatures of each method weren't exact to the specifications of previous tests from background research. The oven method temperature was too low and the torch method temperature was too high. Timing of each method was also not exact, with the samples remaining in the oven overnight, and the samples being torched for 20 seconds each.

| Sample # | Recorded Initial Weight | Weight after heat exposure | Organic Matter Content |
|---|---|---|---|
| 1 | 23.69 | 19.888 | 3.802 |
| 2 | 22.135 g | 22.266 | -0.131 |
| 3 | 31.782 g | 31.653 | 0.129 |
| 4 | 36.303 g | 36.538 | -0.235 |
| 5 | 30.730 g | 28.831 | 1.899 |
| 6 | 36.764 g | 22.326 | 14.438 |
| 7 | 25.651 g | 25.290 | 0.361 |
| 8 | 27.980 g | 32.808 | -4.828 |

After comparisons between pH, elevation, and water proximity information, no conclusions can be made from this data. It's possible samples were compromised or technology was faulty.



*Left photo shows Sample #8, Right photo shows Sample #4.*

As you can see, there are very condensed components or parts of the soil. I believe the negative difference after experiencing the “loss on ignition method” was caused by the condensed parts throwing off the balance of the scale.

MEASURING NPK (MINERAL) LEVELS

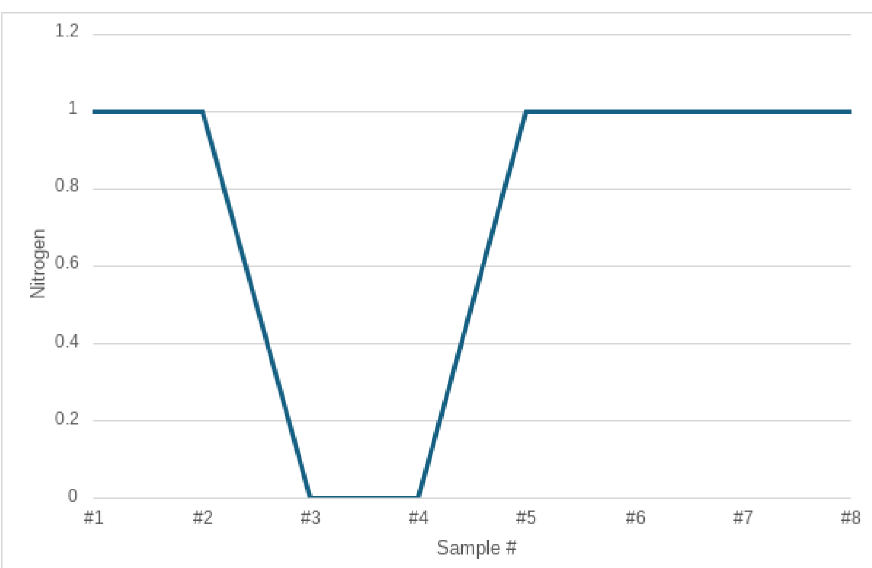
For this part of the experiment, I resorted to using a Rapitest © soil test kit.

1. Create a solution of 1:5 ratio of soil to distilled water.
2. Thoroughly stir the solution to ensure soil dissolves in the water
3. Wait until the soil settles and the solution is clear
4. Using a dropper, fill the test tubes
5. Add the specified capsule powder to the test tube (based on the mineral you’re testing)

6. Set a timer for 10 minutes
7. Determine the mineral content based on the color the solution takes,

| Sample # | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
|---|---|---|---|
| 1 | P1 | P0 | P1 |
| 2 | P1 | P2 | P2 |
| 3 | P0 | P1 | P4 |
| 4 | P0 | P0 | P1 |
| 5 | P1 | P2 | P3 |
| 6 | P1 | P2 | P4 |
| 7 | P1 | P3 | P3 |
| 8 | P1 | P3 | P3 |

| **0** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **Depleted** | **Deficient** | **Adequate** | **Sufficient** | **Surplus** |

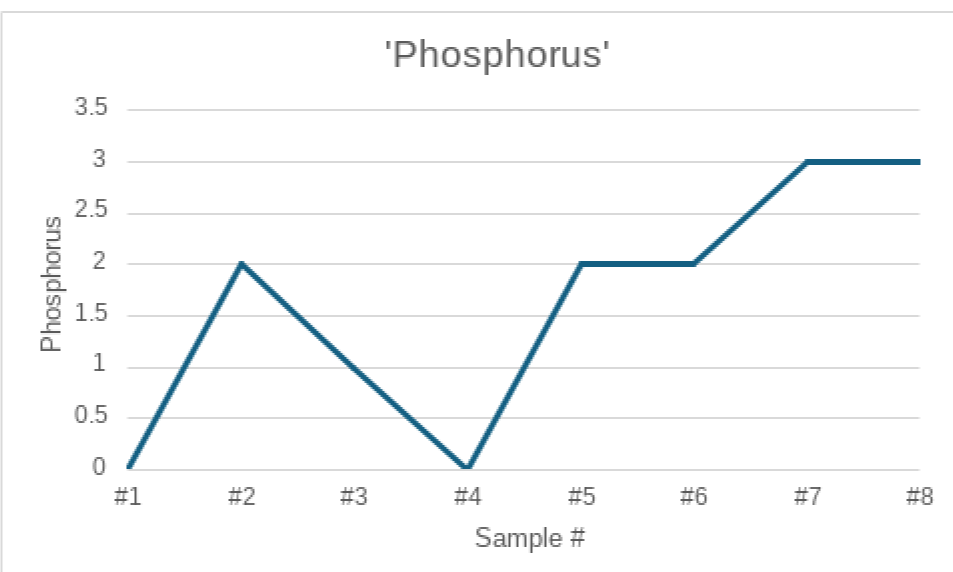



Nitrogen (N) levels of soil samples were insufficient, ranging from 0 to 1 (depleted to deficient). Phosphorus (P)

and Potassium (K) levels were much more variable, with P ranging from depleted to sufficient, and K ranging from deficient to surplus. This nitrogen availability is liking due to the

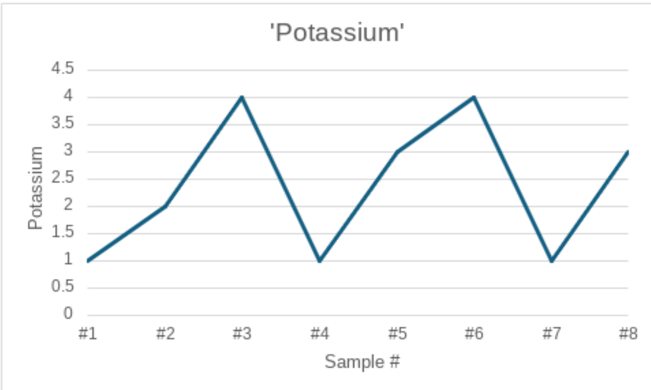
This information delineates slightly from the hypothesis, as NPK concentration was not entirely lacking – N was the primary nutrient that displayed insufficient levels, while P and K were variable or diverse in concentration between respective samples. Nitrogen is more likely to be present in soil if the pH is alkaline, and since these samples displayed alkaline values, we can determine that the lack of N was not due to acidity. Because N originates from organic matter, it's likely it wasn't occurring at sufficient levels because there wasn't sufficient organic matter in originally.

However, this would not explain the lack of N in the presence of P and K, as the two latter elements are also derived from organic matter. As organic matter assessments of this study were erroneous or compromised, we cannot further assess this additional hypothesis without further sample collection and experimentation. Another possible cause of the lack of N is a possible absence of nitrogen fixing bacteria or organisms, such as azotobacter and bacillus. These organisms are key components of the nitrogen cycle by producing N through oxidation. These organisms aren't known to produce P and K. Therefore, their absence would sufficiently explain the absence of N in the presence of P and K.




The variability of P and K levels is more complicated than postulated by

the original hypothesis of this study. Phosphorus levels may be related to the proximity of water source, given that sample #1 has a depleted (0) levels of P and is closest to the Red River, while samples #5 - 8 display adequate to sufficient levels of P and have a greater distance from the Red River.




REVISED HYPOTHESIS

The general impacts of rapid snowmelt within Grand Forks, ND are more complicated than originally assessed, being altered by many different variables. However, slope has been determined to not serve as a major variable of rapid snowmelt and surface runoff, due to the low-altitude trait of the Northern Plains. pH has been accurately predicted as ranging between neutral and alkaline. However, further evidence is required to prove a correlation between soil pH and water proximity. Where mineral concentration is concerned, nitrogen is highly insufficient, due to a possible lack of nitrogen fixing bacteria. A further experiment would seek to collect additional samples of soil and serve for these bacteria using microscopes. Phosphorus and water proximity appear to be correlated, while potassium concentration is not depleted. Further research might include chemical analysis of the Red River itself to search for correlations between the water and soil respective mineral content.

ECOLOGICAL IMPACTS

As global temperatures increase and continue to reach the Midwestern region of the United States, Grand Forks will experience a more persistent and extreme hydrologic cycle. (Broxton, P.D. et. al., 2024) Soil will be further impacted by the issue of rapid snowmelt, including rising pH levels and decreasing NPK content. However, estimates need to consider the decrease in snowfall as a result of this temperature increase, which will also result in alterations in the process of freezing and thawing soil. (Wu and Fang) Additionally, precipitation in the form of rain might, to an extent, “replace” snowfall, leading to an increase in heat, which also serves as a catalyst for rapid snowmelt by providing energy to the system. "Minimizing water-driven soil loss is critical for maintaining the productivity of rangeland ecosystems (Havstad et al., 2009). (Broxton, P.D., et. al., 2024) As runoff from snowmelt increases, negative ecological impacts could include "grass degradation, riverbed sedimentation, and water quality deterioration." (Y. Zheng, X. Shi, F Zhang et al., 2022)

ASSESSMENT OF PLANTS THAT GROW ALONG THE RED RIVER

To assess the plant population growing along the Red River Valley… Results demonstrate that plants growing in this region are well suited to a broad range of pH values.

| Common Name | Scientific Name | Best moisture | pH Range |
|---|---|---|---|
| Narrowleaf willow | *salix exigua* | Moist, well-drained | 5.0 - 8.0 |
| Common tansy | *tanacetum vulgare* | Moist, humus | 6.5 - 7.5 |
| Dandelion | *taraxacum officinale* | Moist, open pores | 4.0 - 8.0 |
| Common hoptree | *ptelea trifoliata* | Moist to dry | 6.6 - 7.5 |
| Sweet wormwood | *artemisia annua* | Well-drained | 6.5 - 8.0 |
| Curly dock | *rumex crispus* | Damp | 6.0 - 7.5 |
| Indian hemp | *apocynum cannabinum* | Alternate between dry and moist | 6.0 - 7.5 |
| Green ash | *fraxinus pennsylvania* | Limited moisture content | 7.5 - 8.0 |

## RESEARCH GAPS AND CHALLENGES

The main challenge of this study was the issue of limited data size. Only eight samples were collected and tested. These samples were collected over a very short period of time and from a small area, and could therefore not account for a diverse body of geologic functions or be connected to specific weather occurrences. Further experiments would collect samples from a much more expansive area across a longer period of time. Determining more appropriate timing techniques would also be beneficial for future experiments, such as determining the reaction rate of calcium chloride with soil to develop more accurate readings of pH values.

**Citations**

A.A. Firoozi. Water erosion processes: Mechanisms, impact, and management strategies. (2022) Results in Engineering, Vol. 24 https://doi.org/10.1016/j.rineng.2024.103237

Z. Wu and H. Fang Snowmelt erosion: A review. (2024) Earth-Science Reviews, Vol. 250 https://doi.org/10.1016/j.earscirev.2024.104704

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